Development of a navigation simulator for helping children evacuate from disasters in schools

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Abstract: This paper examines a navigation simulator for teachers to help students evacuate from school buildings at the time of disasters. Participants were 36 elementary school teachers who agreed to try the simulator that consists of a monitoring device and an input device. In this study, we investigated the following two research questions: (1) Which is easier for the teachers to plan and input evacuation routes — a simulator with two-dimensional images of the school buildings or that with three-dimensional ones? (2) Which is easier for them to use — a simulator with combined conditions or one with separate conditions? These were the results: (1) It was easier for teachers to plan and input evacuation routes on a simulator with two-dimensional images than that with three-dimensional ones; (2) It was easier to use a model with combined conditions rather than one with separate conditions, as this way was faster.

Introduction

Background  
Natural disasters possibly occur anywhere and anytime. According to EM-DAT (n.d.), a database maintained by the Centre for Research on the Epidemiology of Disasters at the School of Public Health of the Université catholique de Louvain in Belgium, 196 natural disasters took place in the world in 2011. It included only the disasters meeting at least one of the following criteria: (1) 10 or more people reported killed; (2) 100 or more people reported affected; (3) declaration of a state of emergency; and (4) call for international assistance (EM-DAT, n.d., Criteria). Thus, it is easily predicted that much more natural disasters than reported by EM-DAT occurred. It is also worth noting that the EM-DAT reported that over 40 percent of those natural disasters took place in Asia while over 80 percent of the numbers of people killed and affected were in Asia. Therefore, it is crucial to prepare for such potential natural disasters in Asia including Japan.
The United Nations has played an active role of reducing the risk of natural disasters on a global scale and Japan has significantly been involved in the U.N. work. The U.N. designed the 1990s as the international decade for natural disaster reduction. In the middle of the decade, 1994, the United Nations World Conference on Disaster Reduction was held in Yokohama, Japan reviewing the progress of this matter. As a result, Yokohama Strategy for a Safer World: Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action was developed. In this Strategy, all participants agree that it is essential to construct a safer world by reducing the risk of natural disasters for sustainable development and to take actions on a global scale for this goal. In order to succeed the progress of the decade and to strengthen the worldwide cooperation on the risk reduction of the natural disasters, the Unite Nations International Strategy for Disaster Reduction (UNISDR) was created in 1999 and adopted by the United Nations Member States in the following year. UNISDR has primarily served to ensure the practice of the Hyogo Framework for Action (HFA), a ten year plan of action on protection against disasters adopted in 2005. HFA was designed based on the review of the progress of the Yokohama Strategy for a Safer World.

UNISDR, in close cooperation with UNESCO, has attempted to promote HFA by coordinating the World Disaster Reduction Campaign. The World Disaster Reduction Campaign, which began in 2006, emphasized importance of education on disaster risk reduction by setting up a theme “Disaster Risk Reduction Begins at School.” One of its major goals was “mainstreaming disaster risk reduction into school curricula” (UNISDR, 2007, vii). UNISDR (2007) reported some good educational practices on disaster risk reduction and showed that numerous educational activities regarding disaster risk reduction have been implemented all over the world. Indonesia is one of the most active in integrating disaster risk reduction into its primary school curricula. The Indonesian government has successfully integrated the topics such as earthquakes, landslides, flooding, and tsunamis into pre-existing subjects such as social studies, science, and physical education rather than developing a new subject dealing with these topics. For example, primary teachers in Indonesia taught flood disaster preparedness by having their students read relevant reports and discuss the topic in their Indonesian Language classes. In sum, although various educational activities have been practiced in the world and the progress of these activities varies, all of them seem to be operated towards development of a common value of prevention in school children.

Japan is no exception to this UNISDR’s attempt but already has had a long history in the field of disaster prevention education. The education has been implemented by following a traditional guidance on disaster prevention that Ministry of Education, Culture, Sports, Science and Technology (MEXT) established (1947. in Sakurai, 2013, pp.147-169). This guidance focuses on how teachers should control a group of school children. For example, if an earthquake or a fire occurred, school children would be trained to wait for their teachers’ instructions and to evacuate by following the teachers’ guidance. This MEXT’s guidance including evacuation instructions has been reviewed and modified little by little by reflecting upon the fact that the types of the disasters that Japan encountered, the situations, and children’s school lives have become more diverse. For example, while MEXT has been attempting to modify its guidance, the Great East Japan Earthquake occurred in its northern part on March 11 2011, and Japan has severely suffered from this disaster. However, many school children in Kamaishi-shi, Iwate managed to evacuate from a huge tsunami followed by the Earthquake by themselves. One of the main reasons for their successful evacuation was that they had received an exceptional disaster prevention education including a unique evacuation strategy called Tsunami-Tendenko, meaning “to evacuate individually” in a Tohoku dialect of Japanese. This strategy, unlike the conventional way of evacuation directed by adults such as teachers, encouraged school children to find out the best evacuation strategy without any adult instructions according to their situations at the time of disasters. However, the disaster prevention education including the Tsunami-Tendenko evacuation strategy is not so common in Japan. One of the factors that prevent this education from spreading to all over Japan is a common perception in Japanese people that teachers are responsible for protecting their students’ lives until their safety is confirmed. To mediate this conflict, MEXT (2013) compiled the report of the well-informed people’s meeting on the Great East Japan Earthquake. It introduced unique models on the disaster prevention education for different grade levels and suggested that it would not be sufficient for elementary schools to develop and practice the conventional way of evacuation in which teachers guide a whole group of students but be necessary to create refuge support measures for various types of rare cases and to conduct relevant education or trainings.
We believe that media equipments and communication systems will, partially or thoroughly, help to implement such measures so that maximum number of school children under the rare cases can be saved. We have conducted a study to develop a portable navigation equipment for lower grade students and a system to direct evacuation routes to the students who are left in school buildings now (see Figure 1). Particularly, we have paid much attention to development of an interface design in the software suitable for teachers’ quick and accurate judgments. We have researched to discover characteristics of cognitive judgments on the interface by adopting an experimental method based on the results of the relevant studies (Morita, 2008, Morita, 2010, Morita, Kawase, Uesugi, and Hotta, 2011, Shimada and Kitajima, 2009 et.al).

We think about the need of such a system based on a specific example as follows. For example, if an earthquake occurred, primary school students would be instructed to follow their teachers’ directions. Therefore, when it takes place in the middle of a lesson, students usually hide themselves under their desks until it stops and follow their teachers’ directions to evacuate. However, if an earthquake happens at recess, students scatter and take a break in and out of school buildings and, therefore, it is extremely difficult, if not impossible, for them to follow their teachers’ directions. As a result, it is necessary to develop an evacuation strategy, especially for schoolchildren who are left inside the school buildings and cannot receive teachers’ directions face to face. To solve these problems, we think that these systems function effectively.

Then, we would like to think about a process and a cognitive characteristic for a teacher to really utilize these systems. First, when we want to operate the devices for evacuation instruction, our operation is divided into two stages; the monitoring stage and input stage. Therefore, it is important to decide if we should operate them successively or simultaneously, because each operation is thought to be different in the cognitive process and load. Adapted for this study, successive operation and simultaneous operation were seen to be equally effective as a means for monitoring and inputting information. In addition, it is generally said that there are three processes involved in order to operate the devices. They are "cognition, judgment, and operation" as a basics of device operation (Ohno, 1998). It was thought that the image evaluation is important to examine usability, too. Therefore, we examined an image evaluation of each operation by dividing into three processes.

On the other hand, when a teacher thinks about the evacuation route out of the school and students may need to move to a different floor, it is necessary to have understanding of a three-dimensional space, in terms of a solid figure (3D). However, if the cognitive load is not gathered by the teacher, it may be easier for the teacher to understand it in a ground plan using a two-dimensional (2D) picture. This would allow for separating the movement into two places that on the ground and that between floors, such as when using the stairs is necessary. It is necessary to develop an interface which considers one’s cognitive abilities so that a teacher can monitor and plan an evacuation route effectively. We should consider to clarify practical conditions through looking at various factors one at a time. We think that we can develop suitable software at the time of an emergency by accumulation of these experiment results.

Figure 1: Design of the system and Disaster situation in this study
Purpose
In this study, the use of navigation simulators by teachers when an earthquake hit was monitored. Both 2D and 3D models of the school were researched as to which would be easier to use when planning an evacuation route. Also investigated was which model was easier to operate that of separate monitoring stages or that of combined monitoring and input stages, when using a navigation simulator.

The expected results are as follows: (1) It is predicted that the 2D simulation will be quicker to solve the problem than the 3D simulation. This is because teachers will most likely be more familiar with looking at the ground plan than the 3D one. However, another thought is that the 3D form may be easier for teachers because it includes the ground plan as well as movement from floor to floor. This would be included in the teachers’ thoughts when they plan the evacuation route. (2) When dividing the monitor stages and input stages it is necessary to plan and memorize an evacuation route which would take more time than combining the steps as would be done with the 3D model.

Methods
Experimental Design
The experiment was 2x2 mixed design. The first factor was how the monitoring and inputting would be done. Combining information versus separating information would be examined. The second factor was the type of interface design that would be used. A 2D model would be compared to a 3D model. The first factor was between-subject variable, and the second factor was within-subject variable.

Participants
Participants were 36 elementary school teachers in Osaka Japan, and they were randomly divided into two groups: (1) Group 1 used the monitoring and input simulators at the same time (combined conditions). (2) Group 2 used the monitoring and input simulators successively (separate conditions). Each participant used the simulators for both 2D and 3D interface design systems (see Table 1).

<table>
<thead>
<tr>
<th>Group</th>
<th>Operation Conditions</th>
<th>Interface Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Combined Conditions</td>
<td>Two-Dimensional Image</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three-Dimensional Image</td>
</tr>
<tr>
<td>Group 2</td>
<td>Separate Conditions</td>
<td>Two-Dimensional Image</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three-Dimensional Image</td>
</tr>
</tbody>
</table>

Table 1. Grouping of the participants

Materials
(1) A monitoring simulator (see Figure 2): A U-shaped four-story school building was selected for this experimental simulation task because it is a common shape of Japanese school buildings. Three monitoring video cameras are installed on each floor. The only video camera at the corner on the second floor is displayed in yellow, which means that it is on. Meanwhile the other video cameras are displayed in black, shows that they are off. The screen at the bottom on the right hand side shows what the working camera captures. In this experiment, four common disastrous events: "crack in the floor," "fire," "broken glass on the floor," and “water pipe explosion" were set as a simulating condition. Each event is attached with one icon at the bottom on the left hand side and each icon can be used as a tag. A simulator with a two-dimensional image of the school building under such a condition and that with a three-dimensional one were created.

(2) An input simulator (see Figure 3): A yellow marker is displayed at every corner on each floor. In order to indicate an evacuation route, all users have to do is to click two markers. Then, the line between the two markers becomes red. Users do the same procedures until an evacuation route is complete.
(3) A post-experiment questionnaire:
Participants were to evaluate the three stages of both the 2D and 3D simulators. Five levels of Likert scale from “Very Easy to Understand” to “Very Difficult to Understand” were adopted in each question.

(a) General – 5 questions were asked about the visibility of the color, design of the screen, objective clarity, emergency usability, and practicality.

(b) Recognition – Was it easy to understand where the dangerous place was? (about a monitoring simulator)
Was it easy to understand where the evacuation route was? (about an input simulator)

(c) Judgment – Was it easy to imagine and construct an evacuation route quickly? (about a monitoring simulator)
Was it easy to tell where a student would need to get to for safety? (about an input simulator)

(d) Operation – Was it easy to control the surveillance camera and to use the labeled functions? (about a monitoring simulator)
Was it easy to input an evacuation route quickly? (about an input simulator)
Procedure

The experiment was carried out with each teacher. The purpose of the experiment and the setting of each situation were explained as well. After giving consent to participate in the experiment, each teacher was taught how to operate the monitoring simulator and the input simulator. A trial task was provided for each participant to make sure they knew how to operate the simulators. Group 1 (those with combined conditions, see figure 4) were given a monitoring simulator and an input simulator. They were told to input an evacuation route, based on the monitoring simulator. Group 2 (those with separate conditions) were shown only a monitoring simulator and then were told to plan an evacuation route based on the monitoring simulator. After the participants came up with their evacuation routes, we collected the monitoring simulators. The participants were then given input simulators and told to input their evacuation route. All participants tried both 2D and 3D experimental tasks. The time it took them to accomplish the experimental tasks was clocked. In addition, three types of routes were available to choose from – Route A, Route B, and Route C. This would make it easier for the participants. These three experimental tasks were counterbalanced by distributing them equally.

Figure 4. The situation of the experiment (2D with combined conditions)

Results and Discussion

Table 2 shows the Means and Standard deviations for time of completing the task. Before analyzing these main data, a one-way ANOVA was performed to confirm the difference of the degree of difficulty of the three experimental tasks as a premise of the analyses. There were no significant differences of degrees between three tasks (F(2,33)=1.62, n.s.). In addition, a t-test was performed to confirm the order effect between 2D and 3D tasks. There were no significant differences between two tasks (2D: t(34)=1.27, n.s., 3D: t(34)=1.05, n.s.).

<table>
<thead>
<tr>
<th></th>
<th>Separate Conditions</th>
<th>Combined Conditions</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2D</td>
<td>3D</td>
</tr>
<tr>
<td>M</td>
<td>174.72</td>
<td>185.61</td>
</tr>
<tr>
<td>SD</td>
<td>(59.68)</td>
<td>(60.17)</td>
</tr>
<tr>
<td></td>
<td>2D</td>
<td>3D</td>
</tr>
<tr>
<td></td>
<td>116.39</td>
<td>156.50</td>
</tr>
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<td></td>
<td>(48.30)</td>
<td>(71.77)</td>
</tr>
</tbody>
</table>

Table 2. Means and Standard deviations for the time to complete the task (seconds)

From these results, we performed a 2×2 ANOVA to assess the differences of device operation and interface design. There was a significant main effect of monitoring and inputting conditions (F(1,34)=6.96, p<.05). In addition, there was a significant main effect of differences of interface designs between 2D and 3D (F(1,34)=4.90, p<.05). However, there was no significant interaction effect (F(1,34)=1.61, n.s.). These results show that combined conditions were easier to work with than separate conditions when monitoring and inputting in these experimental tasks, and the 2D-designed interface was easier to work with than the 3D-one.
On the other hand, the rating scores in the Post-Experiment Questionnaire showed a different tendency when compared with the time needed to complete the tasks (see Table 3.). This shows that a high rating means participants evaluated it favorably.

<table>
<thead>
<tr>
<th></th>
<th>Monitoring</th>
<th>Input</th>
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<tbody>
<tr>
<td></td>
<td>General</td>
<td>Cognition</td>
</tr>
<tr>
<td>2D</td>
<td>M 18.33</td>
<td>3.86</td>
</tr>
<tr>
<td></td>
<td>SD (3.44)</td>
<td>(0.97)</td>
</tr>
<tr>
<td>3D</td>
<td>M 15.19</td>
<td>3.31</td>
</tr>
<tr>
<td></td>
<td>SD (3.76)</td>
<td>(1.03)</td>
</tr>
<tr>
<td>T-test</td>
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</table>

** Table 3. Means and Standard deviations of ratings from the Post-Experiment Questionnaire

From the result of the t-test, when it came to general assessment and monitoring stage, the ratings of 2D tasks were higher than those of 3D tasks. These results support the difference in time to complete those tasks. However, at the input stage, the ratings for cognition level and judgment level show the tendency that 3D tasks were higher than those of 2D tasks, although there was not a significant difference. From these results, it was considered that the 2D interface was easier to identify disaster points in the monitoring stage. Through the monitoring process, participants imagined and constructed an evacuation route in three dimensions. Then, it was supposed that it would be easy to recognize a three-dimensional interface intuitively at the time when participants began to input the information. However, it seemed that the two-dimensional interface was evaluated high in operation level because it was easy and useful for participants originally. Many of the participants commented that there was a three-dimensional image through using two-dimensional tasks. Therefore, it was thought that participants transferred both images with 2D and 3D while they complete those tasks.

**Conclusions**

This study aimed to develop and examine a navigation simulator which a teacher could control for helping students evacuate from school buildings at the time of disasters. From the above results, it appeared that the method of using a remote-controlled evacuation device was fairly practical for teachers. The amount of time to complete each task was about three minutes each. These data show that it is highly possible for teachers to make an evacuation route for students before a secondary disaster occurs.

However, teachers did not work on this experiment in a true state of emergency. At the time of a real disaster, teachers may panic and may not be able to operate the device calmly (see Yamada, Okada, Miyamoto, Yamane, Hayakawa, Mori, Wada, Ohtsuki, Okada, 2009). But many teachers said that they would become quicker at it if they had the chance to practice with this apparatus many times. We think that a future goal would be for teachers to become quicker at operating the device through sufficient practice.

On the other hand, we must develop and compose an easier and more useful interface design that has a lower cognitive load, aimed for practical use. From this study, it was learned that it was easier to use the device which could facilitate monitoring and inputting at the same time, and which had a two-dimensional interface. These results are surely practical and certain, but are only a part of the various factors that need to be considered. However, we believe that it is important to clarify practical conditions through looking at various factors one at a time.
References


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